Effective Paleontological Framing of Climate Change Evidence to Influence Audience Perceptions

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Abstract

The way that media, scientists and others talk about climate change in the messages that they disseminate has an impact on how the public thinks about the topic. This phenomenon is called "framing." To date, research on framing tends to focus on frames related to personal relevance, future effects (e.g. economic benefits or public health risks), uncertainty and attitudes. However, these frames largely ignore the scientific data inherent within climate change messages. While such data may be present in experimental message designs, generally it is not manipulated for study. In this experimental study, we examine the effects of two types of climate change data on research participants' perceptions of climate change: computer-derived climate modeling data and data derived from paleoclimate artifacts and evidence. We also investigate the impact of embedding the two types of data within messages that frame climate change as are either hopeful or desperate. To test these messages, we recruited a population of 417 US participants to participate in a pre- post-test online experimental survey design in which they answered several questions related to intentions, emotions and behaviors towards climate change, then were exposed to one of four experimental conditions (paleoclimate with hopeful language/paleoclimate with desperate language/computer-derived with hopeful language/computer-derived with desperate language), and then answered the same series of questions related to intentions, emotions and behaviors towards climate change. Our results suggest that for our manipulations, a "paleo" frame is more effective at connecting with people on an emotional level. However, our data does not provide definitive support for the practical effects of framing around data type on engagement, intention to seek more information or intention to take action.

Keywords: *framing, climate change evidence, communication, public engagement, paleontology*

1. Introduction

In 2015, over 175 countries, including the United States, joined forces to sign the Paris Agreement, which delineated a set of guidelines for greenhouse gas mitigation and adaptation to combat climate change (United Nations 2015). At that time, the U.S. President was politically liberal. A year later, with a new and politically conservative President in office, the U.S. announced its intention to withdraw from the international treaty. This action emphasized the dichotomous view of climate change held by political factions within the U.S and throughout the rest of the world, as along with Syria and Nicaragua also pulled out of the treaty (Rhodes 2017). Research suggests that the divisive nature of climate change discourse in the U.S. is in part dictated by factors such as political identity, proximity, and social influence, all of which play a significant role on individuals' climate change beliefs and attitudes (Spence and Pidgeon 2010, McCright and Dunlap 2011).

Another factor that can impact these beliefs and attitudes is how information about climate change is "framed" in messages that are disseminated to the public. Framing emphasizes certain aspects of an issue over others, allowing an issue to be viewed in a specific way as determined by the author of the message (Lakoff 2010). When the message is processed by a recipient, the framed information is interpreted through the individual's pre-existing values, beliefs and schema. Therefore, the more relevant a frame is to those predispositions and perceptions, the more effective and influential it is for the individual (Nisbet and Scheufele 2009). Thus, the concept of "framing" has played an increasing role in climate change communication, as communicators seek to find an effective way to encourage target behaviors and to garner support for specific policies. While much of the framing research is focused on pro-environmental messages, message frames also are used in pro-industry messages that seek to counter climate change mitigation efforts.

Over time, research has revealed various frames as effective for climate change communication. These frames often focus on either (or both) of two categories: the impacts of climate change, and/or the socio-cultural factors that influence an individual's reception to climate change (McCright, Charters, Dentzman, & Dietz 2015; Tippett & How 2018; Spence and Pidgeon 2010). This second, more nuanced approach emerged from research

suggesting that science communication needed to convey more than just scientific facts to resonate with audiences (Sturgis and Allum 2004). However, the shift away from a focus on facts also meant that researchers were not looking at what types of facts might resonate with audiences more than others. That is, do message recipients prefer certain types of facts or respond to some types of evidence better than others when it comes to climate change?

Climate change evidence is derived from scientific fields – ranging from computer science to paleontology to physics – and the framing and presentation of the evidence that emerges from these different fields may elicit varying levels of response and engagement. Fields such as paleontology, which rely on data derived from the study of natural processes as well as plant and animal species, represent a more tactile and "relatable" field (Turner 2011). Fields such as computer science, which are often theory-based and backed by algorithms and figures, may suffer from being less "relatable," and from the psychological phenomenon that pre-established opinions are seldom changed by numbers and graphs alone (Kolbert 2017). This inherent difference with the data that undergirds the scientific fields themselves poses an interesting research area that few studies have explored thus far. Here, we briefly review the academic literature on existing climate change frames and their efficacy and evaluate perceived risk and emotional response to risk.

1.1 Framing climate change evidence

Effective climate change framing has been studied extensively over the course of the last twenty years. Previous research has demonstrated the use of frames to emphasize various implications of climate change, such as for the economy, the environment, or public health. For example, messages framed in terms of public health can make climate change more personally relevant and engaging to parts of the population that currently are disengaged (Myers, Nisbet, Maibach, Leiserowitz 2012). Another effective frame is to address individuals' pre-existing beliefs, values, motivations and cultural values (Chess and Johnson 2007). Social normative information can also be used to reiterate the idea that actions that reduce climate impact are socially valuable (Bator and Cialdini 2000). Yet, other research has shown that issue frames that emphasize national security or environmental importance have no overall effect on opinions about the importance of climate change (Singh and Swanson 2017). In this study, 1053 participants were asked to

read a paragraph-long news story that framed climate change as a national security issue, a human rights issue or a consequential environmental issue. The study concludes that individuals' beliefs about the importance of climate change often remain unchanged in the face of issue framing (Singh and Swanson 2017).

The role of emotions in generating advocacy for climate change has also been explored. Previous studies have shown that discrete emotions can influence the way people process information, thus affecting the way they respond in terms of policy preferences (Lu 2015). A 2014 study by Smith and Leiserowitz showed discrete emotions were stronger predictors of support for climate change mitigation policy than socio-demographic factors such as political orientations or even social values. Specifically, messages that emphasize information about what can be done to alleviate climate change increase feelings of hope (Chadwick 2015). A related study tested the effects of political efficacy messages via emotions of hope, fear, and anger across political groups. This research concluded anger was unrelated to climate activism; however, the researchers suggested that the lack of correlation could result from a difference in how anger affects activism across the political spectrum (Feldman and Hart 2016). Therefore, political affiliations have become a central focus of study as well, as research seeks to understand how emotions, values and beliefs moderate reactions and intentions throughout different political groups.

Gain frames that focus on positive outcomes are also more effective than loss frames for increasing positive attitudes towards climate mitigation (Spence and Pidgeon 2010). Framing climate change impacts as distant, as opposed to local, increases perceived severity of those impacts but do not necessarily emphasize personal benefits or positive attitudes (Spence and Pidgeon 2010). A list of five "best practices" for improving public engagement with climate change emphasized the need to present climate change as present, local, and personal, which further illustrated the role of framing in climate change communication (van der Linden, Maibach, Leiserowitz 2015).

Overall, certain frames have emerged as guidelines for creating effective climate change messages. While much framing research has been conducted on climate change impacts and the socio-cultural factors involved, framing research remains necessary for creating

new options and methods for climate change communication (Schäfer and O'Neill 2017). One promising frame strategy involves exploiting the inherent differences between the scientific fields from which climate change evidence is derived, but little is known about the engagement effects of such frames. This area has largely been ignored, as a result of science communication strategies shifting away from the deficit model.

The deficit model stems from a widely-held belief that the lack of public understanding and knowledge of science have thus led towards science skepticism (Ziman 1991). Similarly, if the public were provided with sufficient science, then they will realize that science is reliable, accurate and should be trusted. Thus, the deficit model takes a one-way approach towards communicating science: if the public simply had access to more information, they would be more willing to support science. But critics have long argued against the model on two main points. First, the reason that people are skeptical of science is not because they lack scientific understanding; rather, there are outstanding social factors contributing, for example, to why people do not believe in climate change (Bator and Cialdini 2000). Second, how does one appropriately measure scientific understanding in a population? Even amongst scientists, what is considered fundamental knowledge varies across fields; thus, critics argue that the way that social scientists measure scientific understanding is inherently biased (Sturgis and Allum 2004).

Today, scientific facts and evidence themselves have been viewed as less effective for changing public opinions and attitudes (Sturgis and Allum 2004). But perhaps, an exploration on how to make the *facts* engaging could offset that perspective, since the facts themselves are the basis for any argument for or against climate change. Here, we briefly review the academic literature on existing climate change frames and their efficacy and evaluate perceived risk and emotional response to risk. In the next sections, I present an argument for using paleo-climate framing of climate change evidence as a strategy for higher engagement and action towards climate change.

1.2 Paleontology and the public

Paleontology is the study of fossils to understand how life on Earth has evolved over the course of millions of years in the face of changing climates and ecosystems (Turner 2011).

Paleontology provides a necessary perspective for understanding and assessing how future climates can impact natural systems, as well as how these systems can adapt and mitigate for climate change. Specifically, environmental recorders (like ice cores and fossils) contain physical, chemical and biological features that can be used to explain the causes of past climate shifts. This information can then be extrapolated to understand the extent of modern climate change caused by either natural or manmade effects (Pardi and Smith 2012). For example, shifts in biodiversity can be directly linked to climate change through fossil records (Bates 2009). This physical and quantifiable evidence can help to visualize and make more relevant climate change for a general public, making paleontology an attractive frame for climate change public engagement.

The relevance of paleontology also derives from its long-term outlook on the impacts of climate change. The scales employed are considerably larger than those used in classical ecology and can range over millions of years, corresponding to the lifetime of an average mammalian species (Pardi and Smith 2012). Thus, paleontology provides a method for understanding the role of anthropogenic climate change (ACC) in the context of large-scale, historical timelines. Paleontology evidence, then, inherently dispels one factor of climate change skepticism – the portrayal of anthropogenic climate change as negligibly contributing to the natural climate variation (Hall 2014).

To date, the field of paleontology enjoys a high profile public image and is often considered a "gateway science." Children become easily engaged and interested in science through museums, books and other news about fossils, particularly from dinosaurs and other prehistoric species (Turner 2011). Advances in virtual paleontology have now allowed audiences to interact and engage with virtual fossils and tools, providing an additional platform for public outreach and increasing the public understanding of climate change (Rahman, Adcock and Garwood 2012). Paleontology thus benefits from the public's pre-established perception of worth and engagement towards the field. Certainly, the public image of paleontology remains complicated: while the popularity of the field places great attention and interest on paleontologists and their research, the abundance of media that contains paleontological themes also presents opportunity for misleading and inaccurate information (Lipps 1998). Additionally, dinosaur science largely remains the face of

paleontology, as opposed to evolutionary paleontology – from which most climate change evidence is derived (Turner 2011). Examining the audience impacts of paleontology as a field has thus remained a challenge, as different subsections are likely to elicit different levels of interest and engagement.

1.3 Effective Paleontological Framing

The appeal of framing climate change evidence as derived from paleo-climates and paleo-ecology lies in two particular characteristics. First, paleontology data draws from "natural elements and processes" such as ice core and tree ring formations, laminated sediments, and glaciers and ice caps. This stands in sharp contrast with other climate change evidence, largely derived from complicated mathematical and super-computer simulation models of Earth systems (Edwards 2001). Drawing from prior research on how "perceived naturalness" can influence public perception, the inherent 'naturalness' of paleontological data could elicit more positive attitudes from individuals versus the more complicated and artificial nature of data simulations.

A recent study tested the impacts of framing geo-engineering technology by analogy to natural processes (Corner and Pidgeon 2015). In the study, 412 participants were presented with a factsheet detailing geoengineering as a response to climate change with the two frames (natural analogy and standard description). The study concluded that support for geoengineering was significantly higher when a natural analogy was included in the description. This provided the first systematic evidence that a "naturalness" frame is likely to produce more positive attitudes among the public. A related study on geo-engineering further examined how people think about and relate to the natural world (Corner, Parkhill, Pidgeon and Vaughan 2013). The study claims that nature, while it might not be *well* understood, is considered something *understandable.*

While the differences between paleontology and computer simulation data are not the same as the differences between natural processes and geo-engineering, a similar argument can be made that paleontology is more *understandable.* This is underscored by paleontology's status as the "gateway science" and its higher public profile image among the sciences, as discussed earlier (Turner 2011). Certainly, research is needed before any conclusions can

be drawn regarding whether the "natural" aspect of paleontology can evoke positive action and attitudes in the context of climate change. But this difference within the sciences themselves must not ignored when considering climate change framing and messaging.

The second argument for using paleo-climate frames stems from paleontology's close relationship with animals and wildlife. Paleontologists study fossils of animals and plants to show how Earth's climate has shifted over millions of years. The animal fossils also provide a perspective for how wildlife adapted to those changing climates and for how future ecosystems and animals can be affected by modern climate change (Bates 2009). Paleontology's relationship with animals allows for the inclusion of an additional factor: anthropomorphism. Anthropomorphism applies human-like characteristics, motivations, emotions and intentions to non-human subjects – in this case, animals. Imbuing human characteristics on animals has a powerful impact on whether they are treated as moral agents, worthy of respect and concern (Epley, Waytz and Cacioppo 2007). Anthropomorphism has been frequently used as a tool for conservation messaging, and one study concluded that social connectedness to animals is a strong determinant of conservation behavior (Tam, Lee and Chao 2013). That study further stated that anthropomorphism enhances connectedness to nature, which mediates the link to increased positive conservation behavior. Paleontology, therefore, is a field that naturally allows for anthropomorphism, which can take on various forms (e.g. the use of agentive language to describe animal behavior in the context of climate change) (Root-Bernstein, Douglas, Smith and Verissimo 2013). However, anthropomorphism has limitations: specifically, it is often focused on individual animals and may not necessarily translate to a wider commitment to nature and the environment (McCarney 2018). Thus, additional research will be necessary to conclude if the effects of anthropomorphism on conservation effects translate to paleontology and climate mitigation.

1.4 Research Questions

Here, we explore whether news stories about climate change that feature paleo-climate or climate modeling data resonate more strongly with readers. Specifically, we test if these news stories can illicit differences in the audience's perceived importance of climate

change, perceived risk, and affective response to the risk (such as worry). As such, we have designed experimental manipulations to present climate change evidence as either derived from paleo-climate or climate modeling data, as well as either as hopeful or desperate. The following research questions are explored:

> ***RQ1:*** *Do messages that include paleo evidence for climate change induce stronger intentions to learn more about climate change than messages that include evidence from computer modeling?*
>
> ***RQ2:*** *Do messages of hope induce stronger intentions to learn more about climate change than messages of despair?*
>
> ***RQ3:*** *Is there an interaction effect for messages framed with paleo evidence and hope?*

2 Pilot Study

Participants

We recruited students in communication courses during the spring 2020 semester. Students were able to earn 1 research credit, accounting for 1% of their grade in the class. Participants were sent a link via e-mail to a Qualtrics survey. A total of 68 students began the survey, although only 59 completed responses were recorded. More than 70% of participants were female (n = 43), and all respondents were between the ages of 18-22.

2. 1 Materials and Procedure

The purpose of the pilot study was to determine whether the messages in the articles were clear, as well as the different frames perceived. Specifically, the hopeful/despair manipulations and paleontology/computer data manipulations were tested in order to evaluate and refine the measures and article wording as necessary.

1. Ten items assessing positive (hopeful) climate change attitudes were adapted from the climate change hope scale (i.e. I believe people will be able to stop global warming, I know

there are many things I can do to help solve problems caused by climate change, etc. (Stevenson and Peterson 2016, Li and Monroe 2017). These statements were presented on a five-category Likert-type scale ranging from strongly disagree to strongly agree.

2. Five items about the participant's pre-existing emotions towards climate change were presented on a five-category Likert-type scale ranging from strongly disagree to strongly agree. (i.e. I'm hopeful/worried/interested/relieved/angry/helpless towards the current situation regarding climate change.)

3. Participants next completed four items that assessed their despair towards climate change, adapted from the climate change despair scale (i.e. I feel helpless to solve problems caused by climate change, Problems caused by climate change are out of my control) (Stevenson and Peterson 2016). The subsequent four items measured fatalistic doubt towards climate change and were adapted from previous work on the effects of different types of doubt and hope on climate change mobilization (Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019). The same five-category Likert-type scale was used in this block as the previous two scales.

4. Next, participants were asked to select the frequency (never to always) for which they completed various tasks. These tasks, ranging from "Turn off the lights at home when they are not in use" to "Write a letter to a government leader about climate change," measured pro-environmental behavior and were adapted from the 2016 study by Stevenson and Peterson. Again, the same five-category Likert-type scale was used.

5. Participants were asked to read a short news article. This story detailed how research and data can be used to understand the earth's past and to predict the impacts of climate change on the future, particularly in regards to the declining health of coral reefs in Florida. Depending on the condition, the article either emphasized the data as derived from paleo-climate (using fossils and coral growth rings that record climate changes), or from computer models (using equations and fundamental physical principles). Additionally, the articles varied in their attitudes towards climate change, either as "hopeful" or "desperate."

6. After reading the respective article, participants were asked a series of dichotomous questions about the manipulations. Then, they were exposed to the same four blocks of questions (hope, concern, doubt, pro-environmental behavior) that they answered prior to the article, and were asked to answer the same questions again.

7. At the end of the survey, participants were asked to provide demographic information as well as their name and identification number, so that class credit could be given.

2. 2 Results, Discussions and Modifications

Measures and Scales

Four scales (hope, despair, doubt and pro-environmental behavior) were created from the items. The ten hope items were summed to create a hope score (max = 50, $\alpha = 0.65$). The despair score was calculated as the sum attained from the 5 despair items (max=25, $\alpha = 0.62$), and the doubt score was calculated as the sum attained from the 4 doubt items (max=20, $\alpha = 0.77$). Finally, the pro-environmental behavior score was calculated by adding together the 9 pro-environmental behavior items (max = 45, $\alpha = 0.62$). The Cronbach's alpha was calculated for each scale to test inter-term reliability. However, the values obtained were less than those observed in literature and lower than ideal, indicating the need for modifications both for the measures themselves and the message (discussed in a later section.)

Additionally, paired t-tests were conducted to compare the scale scores before and after exposure to article. For the CD condition, all pre- and post-article scores were strongly and positively correlated ($r = > 0.800, p < 0.001$). There was a significant average difference (AD) between the despair ($t_{11} = 5.007$, $p < 0.001$, AD = -2.33, SD = 1.61) and the pro-environmental behavior score ($t_{12} = -3.407$, $p < 0.005$, AD = 3.15, SD = 3.34). For the CH condition, most pre- and post-article scores were strongly and positively correlated ($r = > 0.800$, $p < 0.001$), except for the pro-environmental behavior score ($r = 0.359$, $p < 0.172$). The pro-environmental behavior score showed a significant AD of 2.06 ($t_{15} = -2.103$, $p = 0.0053$, std. dev: 3.92). Similarly, all pre- and post-article scores were strongly and positively correlated ($r = > 0.700, p < 0.001$) in the PH condition. Again, the pro-

environmental behavior score showed a significant AD of 2.88 (t_{15} = -4.140, p = 0.001, std. dev: 2.77). Finally, for the PD condition, the pre- and post-article scores were moderately and positively correlated (r = > 0.59, p < 0.025), and significant AD was observed for the pro-environmental behavior scores (t_{13} = -4.107, p = 0.001, AD = 3.64, SD = 3.32).

The preliminary data overall showed a significant average increase in the pro-environmental behavior scores across all conditions, suggesting that despite the different frames received, the participants' intentions to engage in pro-environmental behavior increased after reading the stimuli. However, this could also indicate that the participants did not sufficiently perceive the given manipulation. Also, for the CD condition, a significant average decrease was noticed in the despair score, indicating that the desperate condition had the opposite effect of our hypothesis. None of the other conditions resulted in a significant difference across the four scales.

Thus, a series of modifications were made to the main study, to both improve the reliabilities of the scale as well as to increase variance in the results. For pre-existing emotions towards climate change, the question was reworded to "When I think about climate change, I feel…" Nine additional items were added to the scale. Five of those items were to measure hope, adapted from Chadwick 2010, while the remaining four items measured negative affect as a collective emotion (Yang, Kahlor and Griffin 2014). Two additional items measuring personal impact and level of personal impact were added in order to evaluate how the participants felt about climate change prior to the manipulation in regards to perceived hazards.

The despair scale was changed to incorporate items from both the despair and fatalistic doubt for the main study. While the questions in the fatalistic doubt scale conceptually overlapped with despair, doubt was not an explicit manipulation in the stimuli and thus should not be measured as a separate scale. Likewise, even by combining the doubt and despair items in the pilot study, we noted an increase in Cronbach's alpha to 0.77.

A new block of items was introduced into the main study. These items measured past information seeking behavior related to climate change. Since our research questions examined how the stimuli affected intentions to learn about and alleviate the effects of

climate change, we needed additional questions about their climate change information-seeking behavior instead of only pro-environmental behavior. Previous research has shown that information sharing plays a large role in influencing public and media attention/knowledge of a particular topic (Yang, Kahlor and Griffin 2014). The first subsection of the block explored which sources participants sought climate change information from; this would allow us to both understand the extent to which participants actively sought climate-change related information, as well as who they trusted hearing the information from. The second subsection of the block explored the participants' informational subjective norms, which are used to evaluate other people's expectation about one's own climate change information level. This block was also included in the post-article measures.

Finally, another block of questions was added to the survey after the stimuli in order to measure how much attention participants paid to the message. For example, participants were asked to answer the following questions on a five-point Likert scale: "I focused on only a few key points," "I thought about the points made about climate change in the article," etc. These measures can be used to evaluate if a particular frame elicited more interest and engagement, and whether participants were fully reading the stimuli in order to evaluate their genuine effects. Similarly, they can provide an independent variable (message attention) with which post-measure scales (hope, despair and pro-environmental behavior) could be correlated, as previous research has shown that message attention can influence climate change behavior and attitudes (Chadwick 2010).

Manipulation Check and Message Modification

Six Yes/No questions were used to assess the manipulations within the articles. Each of the questions checked for a particular component within the message. For example, for the perceived hopeful/desperate frames, the question asked, "*Did the article refer to climate change in a hopeful/desperate manner?"* Likewise, to test the differences between paleontology data and computer data, participants were asked, *"Did the article refer to data derived from paleontology/computer modeling?"*

A simple manipulation check scores were generated by assigning a "correct" value of 1 for each frame and condition (i.e. for a hopeful condition, a participant would be assigned a "1" if they answered Yes to "Did the article refer to climate change in a hopeful manner."). Thus, the ideal score was 6, and each participant received a score calculated by adding the number of ones they received divided by the ideal score. This score was then averaged across all participants within the same condition. **Table 1** shows the percentages answered correctly for each question given the four different conditions.

Table 1. Percentage of correct answers for the manipulation checks for each of the four conditions.

	% correct			
Question No.	**CD**	**PD**	**CH**	**PH**
1	84.6	35.7	87.5	87.5
2	84.6	71.4	87.5	87.5
3	84.6	35.7	87.5	56.3
4	61.5	78.6	68.8	100.0
5	92.3	78.6	87.5	93.8
6	100.0	71.4	81.3	93.8
All	84.6	61.9	83.3	87.5

Overall, the manipulation check scores indicated that the manipulation was effective, although the PD condition had a lower and less ideal score compared to the rest. Specifically, almost 65% of participants responded that the article referred to climate change in a hopeful manner, whereas the article was meant to elicit emotions of despair. This is inconsistent with the CD condition (also a despair article), where only 15% had answered incorrectly. Also, the same percentage of participants incorrectly answered that the PD article referred to climate modeling. This is similar to the PH condition, where almost half of the participants also incorrectly answered that the article referred to climate modeling. It is likely that the word "climate" in "climate modeling" led participants to

relate the paleo-climate articles with climate modeling. Therefore, modifications were made to the message to account for jargon and confusing wording before conducting the main study.

In the revised messages, the phrases "computer-generated data/climate modeling" and "paleontology/paleoclimate-derived data" were changed to "computer data" and "paleontology data." First, as observed in the manipulation check, the phrase "climate modeling" either is not a common term or is too easily confused with paleo-climate, since both contain the word "climate." Second, it is likely that the unique wording of the compound terms was similar enough that participants selected the incorrect response because they only recalled the second half of the term. Third, the subtle difference between paleontology and paleo-climate is not necessary to differentiate in this study. The sentence "Studying climate change […] can be despairing" was changed to "Studying climate change […] can be depressing." The phrasing of the former is not a familiar way of speech, and while "depress" and "despair" are not the exact same emotion, they have enough similarity for this purpose and helps to increase the readability of the message. Finally, the phrasing of the manipulation checks themselves were changed from "Does the article refer to climate change in a hopeful/desperate manner?" to "Does the article state that the future of climate change is hopeful/desperate?" While the former is still a dichotomous question, it is far more subjective than the latter, and the phrasing is more confusing. These changes were incorporated into the main study.

3 Main Study

3.1 Methods and Materials

We recruited a total of 417 U.S. participants through a national Qualtrics survey distributed online in April 2020. All of the results were kept, as they did meet minimal validation standards (e.g. the survey was completed, there was variability in 50% responses, or took more than half the average completion time). This was further corroborated through Qualtrics' internal screening standards, as all participants were labelled with a "1" for good response. Of all the participants, 50.6% were female and 48.1% of participants were between the ages 18-44. The participants were asked to identify their political affiliation:

32.1% identified themselves as either Very or Somewhat Liberal, 37.6% identified themselves as moderate, and 30.2% identified themselves as either Somewhat or Very Conservative. Participants were randomly assigned to one of four framing conditions: paleo-climate and hopeful (PH, N = 105), computer-modeling and hopeful (CH, N = 103), paleo-climate and desperate (PD, N = 105), and computer-modeling and desperate (CD, N = 104).

When participants arrived at the survey, each consented to the study and were presented with the same introduction defining global climate change. The introduction stated: "The earth's climate is now changing faster than at any point in the history of modern civilization, primarily as a result of human activities, according to the U.S. Global Change Research Program. Global climate change has already resulted in a wide range of impacts across every region of the country and many sectors of the economy."

All participants were exposed to the same blocks of questions and rating tasks, with no changes in the order or content received except for the particular article they were asked to read (containing either a PH, CH, PD or CD article). A full list of the blocks and questions are available in the Appendix. The procedures for the main data collection were the same as the pilot study, with the noted changes incorporated.

3.2 Results

Since the message was significantly modified from the pilot study, another manipulation check was conducted for validation. A series of chi-square analyses were performed on the six questions. The independent variable was the article type (CD, PD, CH, PH) and the individual questions were the dependent variables. Additionally, the percent of correct responses were recorded. These percentages, as well as the chi-square and effect size phi, are reported in **Table 2**. In the first four questions, the four conditions were significantly different ($p < 0.001$). These questions asked about each of the individual frames. In the last two questions, the four conditions were not significantly different. However, this was intended, as the questions asked if the article referred to climate change (question 5) or corals (question 6) and were meant as also serve as an internal attention check. While the overall percentages are good, it is important to note the trend among the lower percentages.

For example, in the PH condition, almost half of the participants incorrectly answered that the message stated the future of climate change was desperate, but more than three-quarters also answered correctly that the message stated the future of climate change was hopeful. Thus, we speculate that while the intended frame was perceived/solidly stuck in their memory, participants answered Yes to the non-intended frame questions merely as a mechanism of ensuring they did not miss anything in the stimuli.

Table 2. Main study chi-square, significance, effect size phi, and percentage of correct answers for the manipulation checks across the four conditions.

				% correct		
Question No.	**χ^2**	**Φ**	**CD**	**PD**	**CH**	**PH**
1	71.48*	0.41	81.7	85.7	53.4	58.1
2	57.21*	0.37	59.6	58.0	79.6	75.2
3	116.0*	0.52	81.7	65.7	92.2	61.9
4	82.16*	0.44	68.3	80.0	63.1	76.2
5	9.526	0.15	86.5	88.6	92.2	78.1
6	1.135	0.052	76.9	81.9	77.7	80.9

*Indicates statistically significant at $p < .001$

A total of twelve scales were created from the survey items. Hope was measured using two different scales. The first is adapted from the Climate Change Hope Scale and measures hope in the context of solving problems caused by climate change (i.e. extent of which individuals believe they can generate and execute solutions towards climate change) (Stevenson and Peterson 2016). The second scale measured hope as a subjective feeling, defined as a feeling of eagerness, anticipation and readiness (Chadwick 2010, Roseman 2001). The third and fourth scales measure positive and negative affect, respectively. Positive affect refers to general positive emotions and expressions towards climate change, and largely consists of the second scale with two additional positive emotions. Likewise, negative affect refers to general negative emotions and expressions towards climate change (Yang, Kahlor and Griffin 2014). The next four scales measured despair, personal impact,

information-seeking behavior, pro-environmental behavior and informational subjective norms. These scales were described previously in the pilot study modifications section. The next scale measured engagement using the following five items: "The article was engaging," "The article was interesting to me," "When reading about the article, I stopped and thought about it," "I thought about the points made about climate change in the article," and "I carefully weighed the point of view in the article." Then, another scale was created to measure intent to seek more information. Specifically, this scale combined future intention-seeking behavior with two items from the pro-environmental behavior scale (In the next six months, I will… "Try to learn more about climate change," and "Read more about climate change."). The item "This article makes me want to learn more about climate change" was included in this scale as well. The last scale measured intent to take action, combining eight items from the pro-environmental behavior scale with the item "This article makes me want to do something about climate change."

While the scales were largely adapted from existing literature, I conducted exploratory factor analyses on each of the scales to determine and confirm their uni-dimensionality. **Table 3** shows the KMO index and percentage of variance explained for each of the ten scales. All the scales were created by averaging the item responses, except for the personal impact scale, which was created as a sum of the two individual response scores. The internal reliability of the scales (as indicated by Cronbach's Alpha) is also included in **Table 3**.

Table 3. Factorability, Percentage of Variance Explained and Cronbach's Alpha for pre and post-stimuli scales.

	Pre-Stimuli			**Post-Stimuli**		
	KMO	**% Variance Explained**	α	**KMO**	**% Variance Explained**	α
Hope	0.92	60.75	0.92	0.90	58.27	0.91
Hope (emotion)	0.86	60.47	0.87	0.90	68.26	0.91
Negative Affect	0.87	54.18	0.86	0.87	60.85	0.87

Positive Affect	0.86	57.13	0.88	0.91	62.01	0.91
Despair	0.90	52.36	0.88	0.92	58.06	0.91
Personal Impact	0.50	87.58	0.86	0.50	91.24	0.90
Informational Subjective Norms	0.89	54.87	0.89	---	---	---
Pro-Environmental Behavior	0.87	44.70	0.88	0.86	44.57	0.88
Message Attention	---	---	---	0.84	45.51	0.77
Engagement	---	---	---	0.87	63.63	0.86
Intent to Seek Information	---	---	---	0.91	77.43	0.95
Intent to Take Action	---	---	---	0.79	41.74	0.82

A series of paired t-tests were conducted to compare the pre and post means for eight of the scales in order to examine the effects of the four individual messages. The scales for Message Attention and Informational Subjective Norms were excluded, as they were only measured either only before or after the stimuli.

For the PD condition (**Table 4a**), there was a significant difference in pre and post-message means for negative affect (PDM = -.184, SD = .67, $p = .006$) and pro-environmental behavior (PDM = -.164, SD = .66, $p < .001$). For the CD condition (**Table 4b**), there was a significant difference in pre and post-message means for pro-environmental behavior (PDM = -.164, SD = .66, $p < .001$). For the PH condition (**Table 4c**), there was a significant difference in pre and post-message means for hope as a subjective feeling (PDM = -.186, SD = .73, $p = .011$), positive affect (PDM = -.188, SD = .73, $p = .009$), and pro-environmental behavior (PDM = -.196, SD = .98, $p = .043$). For the CH condition (**Table 4d**), there was a likely significant difference in pre and post-message means for pro-environmental behavior (PDM = -.166, SD = .87, $p = .057$).

Table 4. Paired t-test results for a) PD condition b) CD condition c) PH condition and d) CH condition.

(a) PD condition

	Paired Diff. Means (pre – post)	**Std. Dev**	**t(104)**	**Sig. (2-tailed)**
Hope Scale	.035	.498	.718	.474
Hope (emotion)	-.095	.601	-1.624	.107
Positive Affect	-.085	.528	-1.640	.104
Negative Affect	**-.184**	**.67**	**-2.829**	**.006**
Personal Impact	-3.771	22.27	-1.735	.086
Despair Scale	-.021	.543	-.399	.691
Pro-environmental Behavior	**-.363**	**.963**	**-3.862**	**.000**

(b) CD condition

	Paired Diff. Means (pre – post)	**Std. Dev**	**t(103)**	**Sig. (2-tailed)**
Hope Scale	.006	.663	.098	.922
Hope (emotion)	.000	.688	.000	1.000
Positive Affect	.018	.672	.274	.785
Negative Affect	.051	.678	.771	.443
Personal Impact	-1.78	23.1	-.788	.443
Despair Scale	.048	.521	.940	.349
Pro-environmental Behavior	**-.417**	**.903**	**-4.710**	**.000**

(c) PH condition

	Paired Diff. Means (pre – post)	**Std. Dev**	**t(104)**	**Sig. (2-tailed)**
Hope Scale	-.085	.591	-1.470	.145
Hope (emotion)	**-.186**	**.734**	**-2.592**	**.011**
Positive Affect	**-.188**	**.727**	**-2.650**	**.009**
Negative Affect	.041	.617	.684	.495
Personal Impact	.381	26.74	.146	.884
Despair Scale	.062	.553	1.156	.250
Pro-environmental Behavior	**-.196**	**.983**	**-2.044**	**.043**

(d) CH condition

	Paired Diff. Means (pre – post)	**Std. Dev**	**t(102)**	**Sig. (2-tailed)**
Hope Scale	-.026	.631	-.417	.678
Hope (emotion)	-.076	.724	-1.040	.301
Positive Affect	-.044	.710	-.624	.534
Negative Affect	-.011	.714	-.161	.873
Personal Impact	-2.445	24.63	-1.008	.316
Despair Scale	-.012	.633	-.208	.836
Pro-environmental Behavior	**-.166**	**.873**	**-1.928**	**.057**

To evaluate possible significant group differences between the participants randomly assigned to the 4 different conditions, a one-way analysis of variance was conducted using the four frame manipulations as the predictor and the nine pre-stimuli scales as the outcomes. The analysis indicated that there were no significant differences between participants assigned to the manipulations.

Next, the associations between the six emotions (hope determined by the Climate Change Hope Scale, hope as a subjective feeling, negative and positive affect, and hope and despair as discrete emotions) and the four remaining scales (evaluation of personal impact of climate change, pro-environmental behavior, information-seeking behavior and information subjective norms) were measured using Person's correlations. **Table 5** shows the correlations for both the pre-message and post-message associations. For the pre-message associations, most emotions show a positive correlation with the impact score, pro-environmental behavior score, information-seeking scores and informational subjective norms score. However, hope as a discrete emotion (measured by the single statement, "When I think about climate change, I feel hopeful.") did not show a significant correlation with the evaluation of personal impact of climate change. Similarly, despair as a discrete emotion (measured by the single statement, "When I think about climate change, I feel desperate.") did not show a significant correlation with the pro-environmental behavior score. Finally, despair as measured by the climate change despair scale showed a significant negative correlation with the evaluation of personal impact of climate change.

Table 5. Correlations between emotions and evaluation of personal impact of climate, pro-environmental behavior*, information-seeking behavior and informational subjective norms for a) pre-message b) post-message*

(a) Pre-Message

	Impact	**Pro-environmental Behavior**	**Info_Seek**	**Info_Subj_Norm**
Hope Scale	.496**	.537**	.556**	.516**
Hope (emotion)	.301**	.466**	.500**	.543**
Positive Affect	.331**	.496**	.530**	.530**

Negative Affect	.470**	.438**	.489**	.489**
Hope (discrete)	.071	.258**	.300**	.365**
Despair Scale	-.141**	.060	.112*	.219**
Despair (Discrete)	.327**	.353**	.383**	.326**

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

(b) Post-Message

	Impact	**Pro-environmental Behavior**	**Info_Seek**
Hope Scale	.522**	.659**	.767**
Hope (emotion)	.255**	.503**	.540**
Positive Affect	.291**	.537**	.589**
Negative Affect	.464**	.438**	.539**
Hope (discrete)	.147**	.387**	.416**
Despair Scale	-.159**	-.061	-.150**
Despair (Discrete)	.789**	.344**	.435**

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

For post-message associations, most emotions also showed a positive correlation with the impact score, pro-environmental behavior score, information-seeking scores and informational subjective norms score. However, despair as measured by the climate change despair scale showed a significant negative correlation with the evaluation of personal impact of climate change and information-seeking behavior; it also did not show a significant correlation pro-environmental behavior.

Finally, we sought to determine if the hopeful/desperate conditions as well as paleo/computer conditions resulted in different feelings and intentions to learn more about and act to alleviate climate change. To do so, we tested whether either of the two independent variables (type of data, attitude of article) or their interaction was statistically significant using a 2 x 2 analysis of covariance (ANCOVA). The dependent variables were the first nine post-message scale scores, while the covariates were the

respective pre-scale scores, as well as message attention. Preliminary checks to validate assumptions of normality, linearity, homogeneity of variances and regression slopes, and reliable measurement of covariates were satisfactory. **Table 6** shows the significance and effect size of the interactions.

Table 6. Significance and effect size of interactions.

	Attitude (H/D)		Data Type (C/P)		Interaction Effect	
	Sig.	**Partial η2**	**Sig.**	**Partial η2**	**Sig.**	**Partial η2**
Hope (CCHS)	**.065**	.008	.702	.000	.208	.004
Hope (emotion)	**.073**	.008	.227	.004	.587	.001
Positive Affect	.837	.000	**.056**	.009	.315	.002
Negative Affect	.229	.004	.282	.003	**.051**	.009
Personal Impact	.514	.001	.754	.000	.373	.002
Despair Scale	.878	.000	.870	.000	.119	.006
Despair (discrete)	.304	.003	.482	.001	.151	.005
Information Seeking	.288	.003	.723	.000	.662	.000
PEB	**.023**	.012	.577	.001	.446	.001

There was no statistically significant interaction between type of data (paleo vs. computer) and attitude (hope vs desperate) on most of the post-message scales, controlling for the pre-message variables. There is a likely significant effect interaction on post-message negative affect, where $p = .051$, partial $\eta 2 = .009$. Within the main effects, there is a likely significant effect on the attitude frame on post-message hope (determined by both the Climate Change Hope Scale and as a subjective feeling ($p = .065$ and $p = .073$, respectively). There is also likely a significant effect on the attitude frame on post-message pro-environmental behavior ($p = 0.051$). Finally, the type of climate change evidence had a likely significant effect on the post-message positive emotion towards climate change ($p = 0.056$).

The potential effect interaction on post-message negative affect was further explored (**Table 7**). Within the "desperate" frames, the negative affect score was 3.252 for computer data (SD = .062) and 3.440 for paleo data (SD = .062). This difference was not observed in the "hopeful" frame. The two likely significant main effects were also further explored in **Table 8**. A higher adjusted mean for positive affect was observed in the "computer" frames (mean diff = .108, std. error = .062). Finally, articles with the "desperate" frame showed a higher adjusted mean average in pro-environmental behavior scores.

Table 7. Difference in adjusted means and std. error for the single likely significant interaction effect on negative affect.

Attitude	**Climate Change Evidence**	**Mean**	**Std. Error**
Desperate	**Computer**	3.252	.062
	Paleo	3.440	.062
Hopeful	**Computer**	3.299	.062
	Paleo	3.244	.061

Table 8. Difference in adjusted means and std. error for the two likely significant main effects observed from Table 6.

Positive Affect		Pro-environmental Behavior Score	
Mean Difference (C-P)	**Std. Error**	**Mean Difference (D-H)**	**Std. Error**
.108	.062	.110	.034

We next sought to determine the effects of the hopeful/desperate conditions as well as paleo/computer conditions on the last three indices (they did not have corresponding pre-message scales): intention to take action, intention to seek more information, and

engagement. To do so, we again tested whether either of the two independent variables (type of data, attitude of article) or their interaction was statistically significant using a 2 x 2 analysis of covariance (ANCOVA). The dependent variables were the post-message scale scores, while the covariates were the respective pre-scale scores. The covariates were added to account for any variation in existing emotions and beliefs towards climate change between the groups. Conceptually, the covariates also served as continuous predictor variables to see if they have any effect on the three indices as well. Preliminary checks to validate assumptions of normality, linearity, homogeneity of variances and regression slopes, and reliable measurement of covariates were satisfactory. **Table 9** shows tests of between-subject effects of the ANCOVA.

Table 9. Significance and effect size of interactions.

	Intent to Take Action (Adjusted R^2 = .674)		Intent to Seek Info (Adjusted R^2 = 0.706)		Engagement (Adjusted R^2 = .471)	
	Sig.	**Partial η2**	**Sig.**	**Partial η2**	**Sig.**	**Partial η2**
Pre_Hope Scale	**.000**	.036	**.000**	.043	**.000**	.040
Pre_Hope (emotion)	.360	.002	.399	.002	.476	.001
Pre_Positive Affect	.271	.003	.282	.003	.916	.000
Pre_Negative Affect	.895	.000	**.040**	.010	.380	.002
Pre_Despair Scale	**.013**	.015	**.000**	.117	.219	.004
Pre_Pro-environmental behavior	**.000**	.407	**.000**	.143	.108	.006
Past Information Seeking	**.017**	.014	**.000**	.093	**.002**	.025
Pre_Informational Subjective Norms	.930	.000	**.000**	.050	**.005**	.019
Type of Data	.160	.005	.989	.000	.777	.000
Attitude Type	**.005**	.019	**.055**	.009	**.023**	.013
Interaction (Data x Attitude)	.979	.000	.912	.000	.593	.001

From the data, we notice that the attitude type (hopeful/desperate) showed a statistically significant interaction across all three indices. However, there is no effect from data type or an interaction between data and attitude type. Interestingly, we note that some of the covariates also have an effect on the three indices. Namely, the Hope Scale and Past Information Seeking Behavior pre-scores affected all three of the indices. Negative Affect had an interaction with the intent to seek more information; Pro-environmental Behavior and Despair pre-scores had an interaction with both Intent to Take Action and Intent to Seek More Information indices. Finally, Informational Subjective Norms had an interaction with Intent to Seek More Information and Engagement indices. **Table 10** examines the main effects of the interactions by attitude type. Higher adjusted means for the three indices were observed in the "desperate" frames.

Table 10. Difference in adjusted means and std. error for the single likely significant interaction effect on negative affect.

Dependent Variable	**Attitude Type**	**Mean**	**Std. Error**
Intent To Take Action	**Desperate**	36.651	.302
	Hopeful	35.447	.303
Intent To Seek More Information	**Desperate**	24.163	.306
	Hopeful	23.326	.307
Engagement	**Desperate**	18.713	.225
	Hopeful	17.984	.226

4 Discussion

The goal of this study was to (a) test the relationship between type of climate change evidence and intentions to learn more about climate change and engage in pro-environmental behavior, (b) examine the effects of messages of hope and messages of despair on intentions to learn more about climate change and engagement in pro-environmental behavior and (c) to examine possible interaction effect between type of climate change evidence and message attitude.

Effect of individual messages on emotions and intentions. The data provided support for a significant negative difference in the pre and post-scores for pro-environmental behavior across all four conditions. This indicates that regardless of the stimuli received, the intentions to engage in pro-environmental behavior increased after the message. A possible explanation is that reading the articles made the participants more aware of their personal actions and consequences on the environment; thus, they may have felt more inclined to want to engage in more pro-environmental behavior regardless of the emotions they felt when reading the articles. For both of the "desperate" frames, the data shows support that information-seeking intentions increased. Additionally, hope as a subjective feeling and positive affect significantly increased in the PH condition, while negative affect increased in the PD condition. The data obtained from the t-tests provide an interesting examination in how each individual article affected participants post-message emotions and intentions. However, they do not provide sufficient support for conclusive statements about the overall effects of the frames (which will be explored in a later section).

Relationship between emotions/feelings and intentions/engagement. While this was not a delineated research question in the study, the relationship between emotions/feelings and intentions towards climate change is very much a subset of those questions. The data in this section provides a cumulative overlook (regardless of the frames applied) at how emotions can influence four factors: evaluation of the personal impact climate change has on a participant, their pro-environmental behavior, their desire to seek information about climate change as well as their informational subjective norms (not measured for post-message). For both the pre-message and post-message associations, a significant positive

correlation is observed between all of the emotions and pro-environmental behavior and intention to seek more information. The data further indicates that the positive correlations are stronger for the two hope scales and the positive affect scale, followed by negative affect scale and the despair scale. However, the trend is not supported by the data for the two discrete emotions (hope and despair). This is likely because the discrete emotions are each measured only by a singular statement, and thus do not provide a well-rounded factor for determining subjective/collective feeling. Overall, the data seems to suggest that gain (positive) frames are likely to be more effective for eliciting stronger intentions to learn more about/act towards climate change. This is consistent with existing literature about the effects of gain frames on climate change.

Effect of frames and their interaction on intention to learn about climate change and engage in pro-environmental behavior. To answer research questions 1 and 2, the main effects of the two independent variables were examined. Specifically, the data shows that the attitude of the article (hopeful/desperate) has a statistically significant effect on hope (determined both by the Climate Change Hope Scale and as a subjective emotion). This is largely expected, as a hopeful frame would have a statistically significant interaction on the post-message hope scale. However, this was not consistent with the negative emotions (including despair). A possible explanation is that hope may be a stronger and more easily perceived emotion as a frame, and is thus likely to elicit stronger and more hopeful responses. One limitation to be noted, though, is that due to the short length of the stimuli, the "hopeful" and "desperate" frames were essentially captured in one paragraph, and may not be extreme enough to thus interact with post-message emotions. Finally, with respect to attitude, there was a significant effect on pro-environmental behavior. Upon further analysis, the data shows that a "desperate" frame yielded a higher adjusted mean for pro-environmental behavior. Also, with respect to the type of climate change evidence, there was a likely significant effect on positive affect. Further analysis showed that a "computer" frame resulted in a higher adjusted mean for positive affect.

Interestingly, this data would partially reject our second research question, as we had hypothesized hopeful articles would elicit stronger intentions to learn about/act towards climate change. Our data instead shows no effect on information-seeking behavior, as well

as that a "desperate" frame elicits higher levels of pro-environmental behavior. In the second ANCOVA, we again note that the "desperate" frames are more effectively for eliciting engagement, intention to take action and intention to seek more information. While at surface level, this seems to contradict current literature on positive and negative frames, a possible explanation lies in a publication examining uncertainty framing (Morton, Rabinovich, Marshall and Bretschneider 2011). Specifically, Morton et. al concluded that in a negative framing condition, low uncertainty resulted in stronger willingness to act. It is plausible that the definitive wording of "…coral will die…" and "…we are past the tipping point…" contributed to the higher observed pro-environmental behavior means.

Similarly, research questions 1 and 3 cannot be supported by the data. Regarding research question 1, we observe that "computer" framed articles elicited higher positive affect. While statistically significant, we similarly note that neither hope as determined by the Climate Change Hope Scale nor hope as a subjective emotion show a similar interaction. A possible explanation is that positive affect is calculated using two additional measures (relieved, interested) that do not conceptually overlap with hope. While the previous section would suggest that a higher affect correlates with a higher pro-environmental behavior score, our data shows there is no significant effect of type of climate change evidence on either information-seeking behavior or pro-environmental behavior.

Lastly, the singular interaction effect occurred regarding negative affect. Specifically, for articles framed as "desperate," stimuli that included paleo data elicited higher levels of "negative affect" compared to stimuli that included computer data. However, this difference was negligible in articles framed as "desperate." This suggests that a computer-data framed article would be more effective in a "desperate" frame, but the evidence-type would not make a difference in the "hopeful" frame. Again, while the previous section would also suggest that a negative affect correlates with a higher pro-environmental behavior score, our data shows there is no significant interactions between type of climate change evidence or attitude on engagement, intent to seek more information or intent to take action.

5 Conclusion

Framing climate change evidence as derived from paleo-climate and paleo-ecology studies holds immense potential for creating effective climate change messaging. Re-framing climate change as derived from different "sciences" could affect the way we emotionally respond to the scientific information, which in turn could affect our environmental intentions. Our pre-post t-tests suggest that for this particular study, the paleo frame is more effective at connecting with people at an emotional level. However, our data suggests that between the fields of paleontology and computer science, there is no significant difference in engagement, intent to take action or intent to seek more information. This could suggest the climate change, as a concept, has already been so deeply ingrained with respect to various social and cultural values, that perhaps the type of scientific data does not play as significant of a role. Still, there were certain limitations in this article – including the length of the article, the use of only text – that could have rendered the data manipulation as ineffective in the larger schema of the article. In this study, we did not observe an interaction effect between type of article and the attitude of the article. Still, climate change evidence remains a crucial aspect of climate change, and additional research is necessary to establish whether it could serve as a possible frame and tool for effectively communicating about climate change.

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Appendix 1: Paleoclimate Survey Table of Items

Item wording	Response options	Source
I believe people will be able to stop global warming.	1=Strongly Disagree, 3=neither, 5=strongly agree	Stevenson and Peterson 2016
I believe scientists will be able to find ways to solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016, and Li and Monroe 2017
Even when some people give up, I know there will be people who will continue to try to solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016, and Li and Monroe 2017
Because people can learn from our mistakes, we will influence climate change in a positive direction.	1=Strongly Disagree	Stevenson and Peterson 2016
Every day, more people care about problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
If everyone works together, we can solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016, and Li and Monroe 2017
At the present time, I am energetically pursuing ways to solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
I know there are many things I can do to help solve problems caused by climate change	1=Strongly Disagree	Stevenson and Peterson 2016, and Li and Monroe 2017
I plan to take some actions to stop climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
When I think about climate change, I feel...		
hopeful	1=Strongly disagree	Chadwick (2014)
worried	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
interested	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
eager	1=Strongly disagree	Chadwick (2014)
optimistic	1=Strongly disagree	Chadwick (2014)
relieved	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
desperate	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
positive	1=Strongly disagree	Chadwick (2014)
angry	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
enthusiastic	1=Strongly disagree	Chadwick (2014)

helpless	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
encouraged	1=Strongly disagree	Chadwick (2014)
concerned	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
anxious	1=Strongly disagree	Yang, Kahlor and Griffin (2014)
What is the likelihood that climate change is going to impact your life in the next 20 years?	0-100 scale	Kahlor, L. A. (2007).
If it does impact your life, how serious would that impact be?	0-100 scale	Kahlor, L. A. (2007).
I feel helpless to solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
The actions I can take are too small to help solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
Problems caused by climate change are out of my control.	1=Strongly Disagree	Stevenson and Peterson 2016
Climate change is such a complex problem. We will never be able to solve it.	1=Strongly Disagree	Stevenson and Peterson 2016
I personally do not intend to do much to stop climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
It will be too costly for society to reduce climate change.	1=Strongly Disagree	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
Humans can't affect climate change because you can't fight nature.	1=Strongly Disagree	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
It's already too late to do anything about climate change.	1=Strongly Disagree	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
People have higher priorities to worry about than climate change.	1=Strongly Disagree	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
Turn off the lights at home when they are not in use	1=Never, 2=rarely, 3=sometimes, 4=often, 5=always	Stevenson and Peterson 2016

Ask my family to reuse some of the things we use (i.e. use things more than once)	1=Never	Stevenson and Peterson 2016
Try to learn more about climate change.	1=Never	Yang, Kahlor and Griffin (2014)
Read more about climate change.	1=Never	Yang, Kahlor and Griffin (2014)
Ask other people to turn off the water when it is not in use	1=Never	Stevenson and Peterson 2016
Close the refrigerator door while I decide what to get out of it	1=Never	Stevenson and Peterson 2016
Recycle at home	1=Never	Stevenson and Peterson 2016
Seek out more information about climate change online.		Yang, Kahlor and Griffin (2014)
Walk for transportation	1=Never	Stevenson and Peterson 2016
Bike for transportation	1=Never	Stevenson and Peterson 2016
Write a letter to a government leader about climate change	1=Never	Stevenson and Peterson 2016
Attend a climate change protest of awareness rally	1=Never	Stevenson and Peterson 2016
I actively seek information about climate change from the following sources:	1=Strongly Disagree	
The news media	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
The government	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
Environmental Groups	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
Scientists and Universities	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
The energy industry or Power companies	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
Google Searches	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
Social Media	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
Conversations with Family and Friends	1=Strongly Disagree	Yang, Kahlor and Griffin (2014)
When I come across information about climate change, I usually understand it.	1=Strongly disagree	
My friends and family expect me to be up-to-date on information about climate change.	1=Strongly disagree	
People who I care about expect me to know something about climate change.	1=Strongly disagree	

Climate change is a regular topic of conversation with my friends and family.	1=Strongly disagree	
I understand most of the information I see or hear about climate change.	1=Strongly disagree	
The topic of climate change is way over my head.	1=Strongly disagree	
Others expect me to seek information about climate change.	1=Strongly disagree	
When I come across information about climate change, I can separate fact from fiction.	1=Strongly disagree	
It is expected of me that I seek information about climate change.	1=Strongly disagree	
Did the article state that the future for climate change is desperate?	1=Yes, 2=no	Manipulation check
Did the article state that the future for climate change is hopeful?	1=Yes	Manipulation check
Did the article refer to computer-generated data?	1=Yes	Manipulation check
Did the article refer to paleontology?	1=Yes	Manipulation check
Did this story refer to computer simulations?	1=Yes	Manipulation check
Did this story refer to corals?	1=Yes	Manipulation check
The article was engaging.	1=Strongly Disagree	
The article was interesting to me.	1=Strongly Disagree	
This article makes me want to learn more about climate change.	1=Strongly Disagree	
This article makes me want to do something about climate change.	1=Strongly Disagree	
I focused on only a few key points.	1=Strongly Disagree	
I didn't spend much time thinking about it.	1=Strongly Disagree	
I skimmed through the article.	1=Strongly Disagree	
I stopped and thought about it.	1=Strongly Disagree	
I thought about the points made about climate change in the article.	1=Strongly Disagree	
I carefully weighed the point of view in the article.	1=Strongly Disagree	
Every day, more people care about problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
I believe people will be able to stop global warming.	1=Strongly Disagree	Stevenson and Peterson 2016, and Li and Monroe 2017

I believe scientists will be able to find ways to solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016, and Li and Monroe 2017
Even when some people give up, I know there will be people who will continue to try to solve problems caused by climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
Because people can learn from our mistakes we will influence climate change in a positive direction.	1=Strongly Disagree	Stevenson and Peterson 2016
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I personally do not intend to do much to stop climate change.	1=Strongly Disagree	Stevenson and Peterson 2016
It will be too costly for society to reduce climate change.	1=Never	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
Humans can't affect climate change because you can't fight nature.	1=Never	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
It's already too late to do anything about climate change.	1=Never	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
People have higher priorities to worry about then climate change.	1=Never	Marlon, Bloodhart, Ballew, Rolfe-Redding, Roser-Renouf, Leiserowitz, Maibach 2019
Turn off the lights at home when they are not in use	1=Never	Stevenson and Peterson 2016
Ask my family to reuse some of things we use (use things more than once)	1=Never	Stevenson and Peterson 2016
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Recycle at home	1=Never	Stevenson and Peterson 2016
Walk for transportation	1=Never	Stevenson and Peterson 2016
Bike for transportation	1=Never	Stevenson and Peterson 2016

Seek out more information about climate change online.	1=Never	
Write a letter to a government leader about climate change.	1=Never	Stevenson and Peterson 2016
Attend a climate change protest or awareness rally.	1=Never	Stevenson and Peterson 2016
Try to learn more about climate change.	1=Never	
Read more news about climate change.	1=Never	
(In the next 6 months), I plan to seek more information about climate change in the future.	1=Strongly Disagree	Kahlor 2007
(In the next 6 months), I intend to find out more about climate change.	1=Strongly Disagree	Kahlor 2007
(In the next 6 months), I will try to seek as much information as I can about climate change.	1=Strongly Disagree	Kahlor 2007
What is your gender?	1=Male 2=Female 3=Nonbinary	
Select the political ideology you most align with.	1=Very Liberal, 2=somewhat liberal, moderate, somewhat conservative, very conservative	
Select the highest level of education you have received.	1 = less than HS 2 = HS 3 = some college 4 = Bachelors or Higher	

Appendix 2: Stimuli

RESEARCH NEWS

Computer Data Show a Desperate Future in Battle Against Climate Change

Computer-generated data can tell us stories about the earth's past and help scientists predict the impacts of climate change on our future. Scientists now know how to use **computers** to simulate how deep-sea corals off the coast of Florida have responded to environmental changes for hundreds of years.

Virginia Will, professor of earth and planetary sciences at the University of Florida, Gainesville, studies computer modeling of climate change. **Climate models** use **equations and fundamental physical principles** to represent the processes and interactions that drive the Earth's climate.

Studying climate change **using computers** can be **depressing**, says Dr. Will, because there are clear examples of how **desperate** the situation can be for coral over time. "We are essentially **past the tipping point** with climate change now," she said. "Our **models** show that coral will **die** in the face of a **rapidly** changing climate."

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RESEARCH NEWS

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RESEARCH NEWS

Paleontology Data Show a Desperate Future in Battle Against Climate Change

Deep-sea corals and fossils can tell us stories about the earth's past and help scientists predict the impacts of climate change on our future. Scientists now know that deep-sea corals off the coast of Florida live for hundreds of years—and they record a ring for every year of their growth, just like trees, with clues about the past hidden in every ring.

Virginia Will, professor of earth and planetary sciences at the University of Florida, Gainesville, studies coral within the field of **paleontology**, which focuses on evidence of past climate change found in **fossils and living specimen.**

Studying climate change through **paleontology** can be **depressing**, says Dr. Will, because there are clear examples of how **desperate** the situation can be for coral over time. "We are essentially **past the tipping point** with climate change now," she said. "Our **paleo** data show coral will **die** in the face of a **rapidly** changing climate."

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